Urban Air Mobility Fleet Manager Gap Analysis and System Design

Prepared for the NASA Urban Air Mobility Sub-Project

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1. Background

NASA's Urban Air Mobility (UAM) Sub-Project is engaged in research to support the introduction of air taxis into the National Airspace System (NAS). Such operations will require a range of communication, navigation, and surveillance systems. Air vehicles for UAM are under development and will initially have human pilots. Separation from other aircraft, obstacles, and weather may be a pilot responsibility or provided by an operator's ground-based systems. Eventually, air taxis may be flown from the ground or fly autonomously.

"An air taxi could be defined as a flying vehicle with a range of 50-120 miles, carrying two to four passengers and cruising at an altitude of 3,000 to 5,000 ft. In the near term, based on the current battery technology, the most-common commute might be a 50-mile round trip with two short vertical takeoffs and a 30-minute energy reserve on a single battery charge." [1]

UAM vehicles will carry passengers and cargo like conventional aircraft, but there the similarities disappear. Table 1 is a comparison of the two classes of vehicles.

Present Day Aviation	Urban Air Mobility
Large aircraft (B777 is 774,600 pounds)	Small aircraft (2,000 - 4,000 pounds)
Many passengers (hundreds)	Two to four passengers
Highly structured airspace	Less structured airspace
Local and high-altitude weather data	Detailed weather data for low altitudes
Voice radio communications	Digital data and voice communications
Operations segregated from public	Operations integrated with public
Robust performance in weather	Highly susceptible to weather
NAS-wide air traffic control (ATC) services	Operator-provided ATC services
Scheduled operations	Unscheduled operations
Avoids urban areas	Operates in urban areas
Sophisticated airports	Simple landing pads or "land anywhere"
Highly trained flight crews	Minimal flight crew training
Partial reliance on automation	Heavy reliance on automation
Complex maintenance requirements	Simple maintenance requirements

Table 1. Comparison of conventional and UAM operations.

Given the history of conventional (Part 121 and Part 135) operations, it is clear that dispatch functions will be required for UAM. The FAA may mandate dispatcher services, as with passenger and cargo aircraft today.

Dispatcher functions include:

- Evaluate weather and hazards
- Create and deliver flight plans

- Monitor flights and intervene as needed for:
  - Weather changes
  - Delays
  - Aircraft system problems
  - Fuel reserves
- Monitor fleet schedule
- Manage aircraft maintenance

At this time, the role of the UAM ground operator is not defined. For air taxis, there may be advantages in combining remote piloting duties with dispatcher tasks. For now, we will treat the UAM dispatcher as a standalone position with its own workstation. To distinguish this role from conventional dispatch operations, we will call the UAM dispatcher the "Fleet Manager" or FM.

This report presents a gap analysis, data and capability requirements, and workstation design concepts for the UAM FM position. The gap analysis focuses on the differences between the tasks of the airline dispatcher and FM. Dispatcher tasks are listed along with the anticipated tasks for the FM. Small Unmanned Aircraft Systems (sUAS) Traffic Management (UTM) concepts that may apply to UAM guide these analyses.

UTM characteristics relevant to UAM are:

- Operator is responsible for maintaining separation from other aircraft, airspace, weather, terrain, and hazards and ensures separation at the time of operation planning
- Service-oriented architecture with third-party providers of:
  - Traffic flow management (including scheduling, sequencing, and spacing)
  - Airspace directives/constraints
  - Separation management
  - Weather reporting and forecasting
  - Emergency management
  - Flight planning
  - Flight monitoring
  - Communications, navigation, and surveillance
  - Data systems
- Increasingly autonomous operations (e.g., pilotless vehicles)

In the following table, each airline dispatcher task is described along with the corresponding FM task. Table 3 lists FM information and capability requirements. Following this, an initial design for an FM workstation is presented. This includes the layout of the user interface (UI) and functions assigned to each element. This does not include a detailed UI design, which may be completed in follow on work.

2. Gap Analysis

In Table 2, current airline dispatcher tasks are listed with the comparable FM task. Tasks in bold have significant differences compared to conventional dispatcher tasks.

Airline Dispatcher Task	Fleet Manager Task
Dispatcher arrives for their shift and is briefed by the outgoing dispatcher.	**The outgoing FM uses their software to note and communicate issues to the incoming FM. The FM's workstation should have a software tool that summarizes all of the important information to be passed on to the relief FM. The next shift may be manned at a different office in another part of the country.**
Electronically logs into the dispatcher workstation.	The FM logs into their workstation.
Launches flight planning system.	**FM plans the flight with different information compared to that used for large aircraft. The UAM route structure will most likely use lat/longs for waypoints, pre-defined routes, corridors, etc.**
Launches aircraft situational display (ASD) system.	**FM launches their ASD. The ASD is a primary tool for the FM. However, due to the shorter range of an air taxi, the ASD must be refined to have the ability to view geographical and weather data on a micro scale, using new sensor suites.**
Launches communication console.	FM launches the UAM communications console (e.g. radio, cell phone, text messaging, etc.).
Identifies any electronic messages that were not observed during the turnover process.	FM uses their communications console to identify any new messages.
Gains situational awareness of airborne inventory and planned flights by reviewing the current weather.	**FM uses weather information focused on low altitude operations.**
Gains situational awareness of airborne inventory and planned flights by reviewing any Notices to Airmen (NOTAMS) that affect flight performance.	**FM accesses information relevant to low altitude operations. This may not be included in NOTAMS, or may be captured in new, localized NOTAM-type systems.**
Gains situational awareness of airborne inventory and planned flights by reviewing ATC initiatives in effect.	**FM reviews specific information about low-altitude traffic situations. This may include data on reservations for localized urban routes/corridors and landing zones.**
Reviews company compliance documents that implement any policy changes, such as a "Read Before Fly."	Reviews relevant company documents. This provides the ability to keep up with changes, especially during the early stages of UAM.

Airline Dispatcher Task	Fleet Manager Task
Reviews entire network to gain awareness of any out of service aircraft.	FM consults displays to understand the state of all aircraft to maintain situational awareness of the fleet.
Cancels portions of the schedule (or flights) if aircraft are out of service.	**Cancels scheduled flights, as needed. For those UAM operations that are on demand, the FM changes aircraft availability data.**
Examines payload information for each respective flight.	**Examines payload information for air taxi flight. The payload capacity and weight/balance are critical due to the small size of an air taxi.**
Composes the Dispatch Release by entering the necessary data, such as weather and performance information.	**UAM may use a UTM-like "Operation Plan" (rather than a flight plan) that is not submitted to the FAA. Local authorities may require "intent plans" or slot requests.**
Reviews the aircraft's maintenance record and respective Minimum Equipment Lists (MEL).	FM reviews the state of assigned aircraft to maintain awareness of maintenance issues. An MEL is needed for each type of air taxi.
Examines the route of flight against any impacting condition.	**Checks planned air taxi flight routes. Variations will exist since altitudes are much lower and areas of operation are different (urban areas).**
Examines potential air traffic constraints.	**FM reviews low altitude air traffic constraints relevant to UAM operations.**
Adds additional fuel for any impacting condition (ATC, weather, other hazards).	Fuel or battery reserves are determined before each flight.
Identifies the best altitude for the flight with respect to wind and turbulence. The shortest distance may not always be the most efficient due to high-altitude wind components.	**FM selects altitude preference in flight planning software. Altitude selection options may be very limited, depending upon route structure.**
Submits the flight plan to the FAA.	**FM submits "Operation Plan" to the a UAM Service Supplier (USS) or other entity.**
Transmits the Dispatch Release to the respective flight crew.	Dispatch Release is transmitted to the aircraft and vertiport.
Amends the Dispatch Release if necessary (additional payload or developing weather considerations).	Dispatch Release is modified if needed (e.g., change in passenger complement).
Monitors crew duty time information	Monitors mandated crew duty time limits for air taxi pilots.
Follows airborne flights with respect to weather or any other impacting condition.	**FM views progress of flights. ASD must have detail needed to monitor low altitude flights for weather and other hazards.**
Maintains situational awareness of fuel consumption while the aircraft is airborne.	Monitors fuel or battery state from downlinked data.

Airline Dispatcher Task	Fleet Manager Task
Monitors and enters pilot reports (PIREPS)	PIREPS are similar despite differences in path and altitude. These are transmitted to the operator and USS.
Maintains situational awareness of airports that are nearby and suitable if an abnormal situation or emergency arises.	FM provides guidance for contingency events. Suitable diversion or emergency landing sites along the route are determined prior to flight.
Ensures that aircraft that require servicing and maintenance are routed to airports where parts and technicians are available.	FM identifies vertiports with maintenance capabilities and routes air taxi vehicles accordingly.
Maintains and saves all necessary paperwork for a prescribed time.	The system keeps historical safety data.
Maintains database of all airports and any necessary infrastructure changes to them.	FM keeps track of information about vertiports.

Table 2. Airline dispatcher and FM tasks.

3. Data and Capability Requirements

Table 3 shows the data and capabilities that are required for the FM to perform their tasks.

Type of Information	Required Data and Capabilities
Shift Briefing	- Current and projected impacts of crew roster - Aircraft complement and availability - Gate assignments - Weather - Airport closures - Outgoing FM notes - Company policy changes - Emergency procedures in progress - FAA/local authority publication changes - Current customer status (complaints) - Current events and public events - Ground traffic - Information technology or computer-related issues or changes

Type of Information	Required Data and Capabilities
Map	- Aircraft position, identifier, speed, heading, altitude, and flight plan - Flight corridors - Speed and descent profiles - Trip length - Conflict prediction and status - Flight path manipulator (in the event of a contingency) - Alternate route suggestions - Human-made and natural obstructions (e.g., buildings, trees, hills, etc.) - Temporary Flight Restrictions - Special Use Airspace - Energy/battery conservation suggestions/route optimization - Landing area issues - Noise regulations that affect vehicle choices - Other aircraft position, identifier, speed, heading, altitude, and flight plan - Reception obstruction areas - Vertipad/vertiport detailed map view with traffic - Vertipad/vertiport status - Airspace corridor saturation monitor - Emergency and safety related notices affecting flights

Weather	- Very detailed weather information for the altitudes and areas of concern
	- Very rapid surface to 5000 feet weather changes
	  - Micro-scale weather detection and prediction
	  - Barometric pressure
	  - Temperature
	  - Relative humidity
	  - Dew point
	  - Wind speed and direction
	  - Icing
	- Detailed wind flows for urban canyons, structures, topographical areas, vegetation (e.g., forests, valleys, bridges, etc.) with a few meter resolution
	- Ice formation on the ground
	- Localized ceiling and fog
	- Weather integration into decision-making

Type of Information	Required Data and Capabilities

Aircraft	- Aircraft type
	- Fuel/battery capacity, range, and remaining
	- Aircraft energy/consumption monitor
	- Time to charge battery
	- Payload:
	  - Aircraft capacity
	  - Weight
	  - Manifest
	  - Loading notes
	- Routing
	- Human pilot or ground pilot
	- Safety procedures
	- In flight route optimizations
	- Deferred maintenance items
	- Repair and maintenance data
	- Onboard system status

Communications	- Downloads of updated regulations, management advisories, etc. - Information about crew scheduling changes - Security or emergency items (terrorism threats, reroutes, medical emergencies) - Voice and text links with pilot - Messaging with passengers - Voice and data communications with ATC/local authorities - Data communications with service suppliers - Two-way data contact with aircraft (equipment status, fuel/battery level, etc.) - Voice and text with vertiports - Voice and text with maintainers
System	- Replacement vehicle availability - Live repair turnaround estimates - Company system status (communications, facilities, personnel, etc.) - Gate assignments - Crew changes - Curfew issues - Noise footprint - Noise abatement - Recommendations for procedural, route, or other optimizations - Alarms or warnings of upcoming system downtime and faults - Credential verification, training level of FM to operate under current conditions - Role management and delegation - Backup pilot for emergency events

Table 3. FM data and capability requirements.

4. <u>User Interface Goals</u>

FMs will be challenged by the number of flights they must control and the sheer complexity of low-altitude vehicle management.Therefore, information displays are forward-looking and assist the FM with suggested courses of actions rather than just displaying data.

System capabilities include:

- Predictive interactions as a core design principle
- Optimize FM to vehicle management ratio
- Decrease training needs of FMs vs. airline dispatchers
- Enhance safety considerations of low altitude, automated flight conditions

The UI architecture provides two modes. One mode reveals recommended interface actions based on user tasks, with the computer looking ahead and presenting calculated options. If the user wishes to drill down to understand the process by which the system is making recommendations, or perhaps create other courses of action, a “Behind-the-Curtain” or detail mode of operation can be accessed. The Behind-the-Curtain views are designed with the goal of being subordinate to the assisted mode.

The FM interface uses a single, large display. Information in the interface is shared. An example might be that the user chooses a route, the impact is noted as an issue during or after creation of the route, a map graphically shows the issue, and the user can take several actions including a computer-generated option. The user communicates the chosen action to others, logs the issue, and monitors the flight path.

Three actions are at the center of the architecture: <u>Prediction, Monitoring, and Execution</u>.

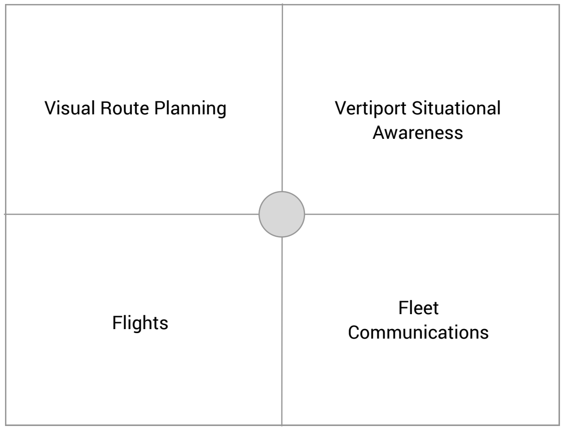
<u>Prediction</u>: This is an assisted automation mode. The system is aware of the user’s intended actions and unobtrusively makes recommendations based on a larger set of data than is available to the user, and with greater depth of algorithmic process. For example, a change in vertipad landing area causes extensive rolling delays. The computer generates efficient responses and weights those choices for the user.

<u>Monitoring</u>: Situational awareness is maintained pre-flight, in-situ, and post-flight. This allows users to understand how the computer’s choices are being carried out and/or change the plan based on factors perhaps outside of the system’s algorithms.

<u>Execution</u>: The user puts a plan in place, such as authorizing a flight the system has recommended or that the user has constructed. The UI makes user decisions and their effects obvious, showing timing and pertinent state data feeding back to Monitoring.

The following designs represent a notional interface; that is, wireframe examples of what an FM tool would look like based on a Prediction, Monitoring, and Execution architecture. It is low-fidelity and conceptual, as presented here.

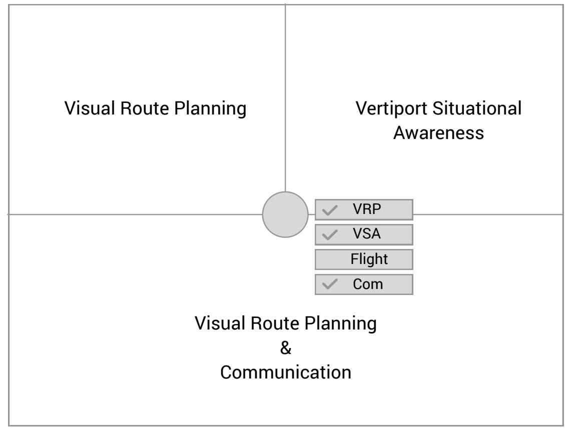
Interface layout 1



The maximum number of windows is four. The user can drag and drop the controller at center (indicated by a gray circle) to resize all windows simultaneously.

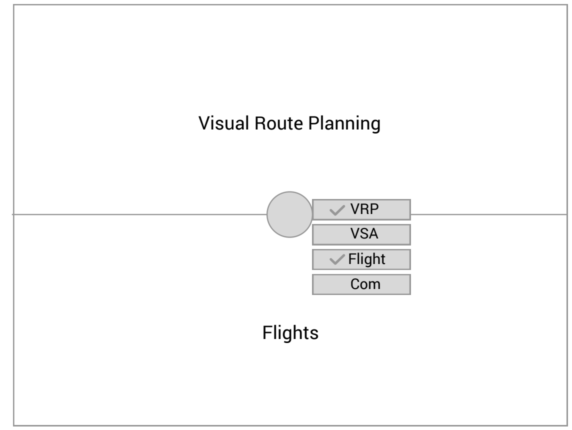
Starting with the top left quadrant and going clockwise:
- Visual Route Planning for assisted optimization
- Vertiport Situational Awareness for monitoring
- Flight monitoring
- Fleet Communications

Interface layout 2

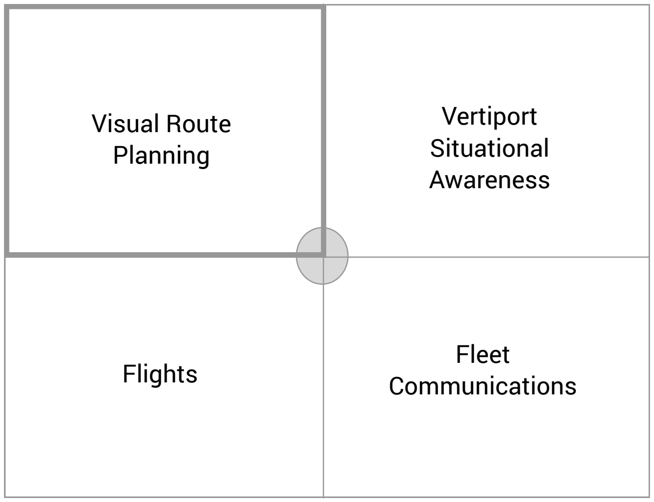


To change the number of windows, right-click on the controller (indicated by a gray circle). A menu appears allowing users to toggle on/off each of the four windows. Toggling off a window results in a three window view as in the example above.

Interface layout 3



Toggling two windows off results in a split view as shown in the example above. Users may toggle on/off windows as necessary.



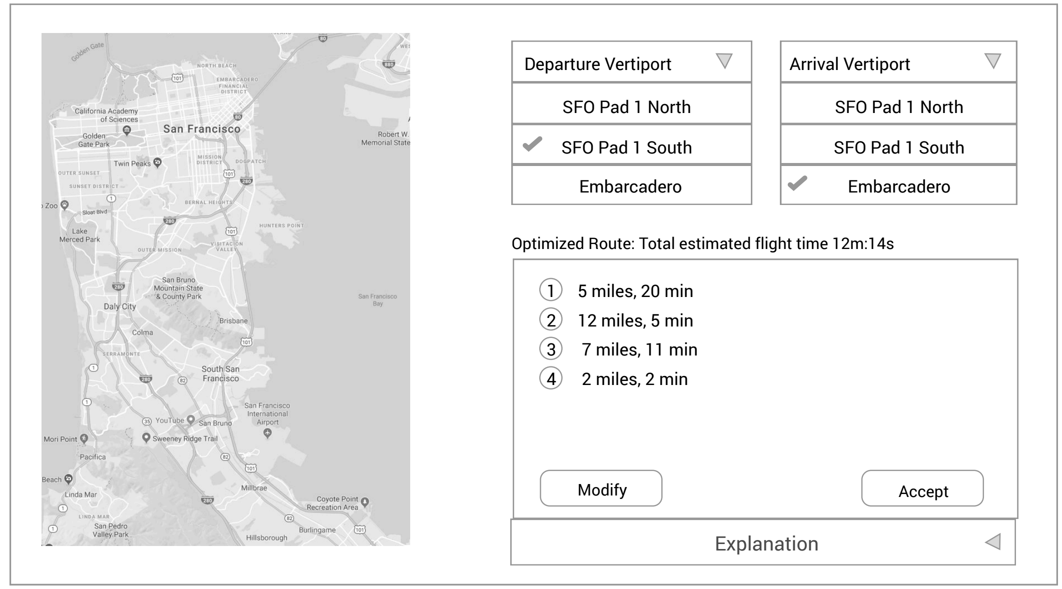
Prediction

The Visual Route Planning window allows users to access computer-recommended optimization results simply by selecting departure and arrival vertiports .

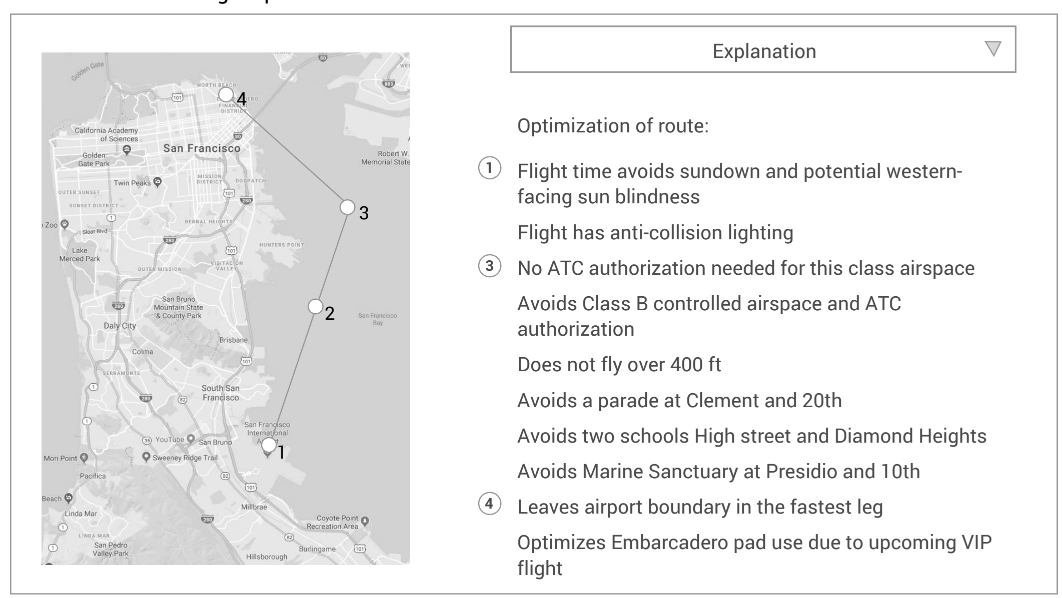
The figure at top right shows how users can select the departure and destination. Automated results appear as a description below and visually on a map. Users may accept the suggested route or modify it.

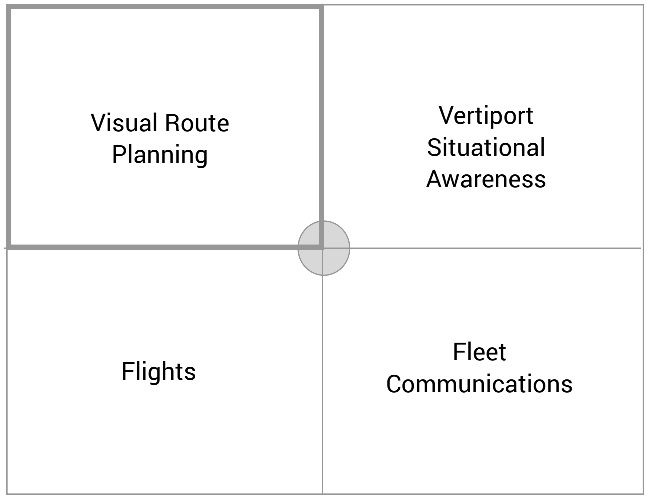
If users wants to find out more about why a particular route was suggested, they can select “Explanation” to open up a detailed description as shown in the figure at bottom right.

Visual Route Planning: User selects vertiport departure and arrival. System computes options.

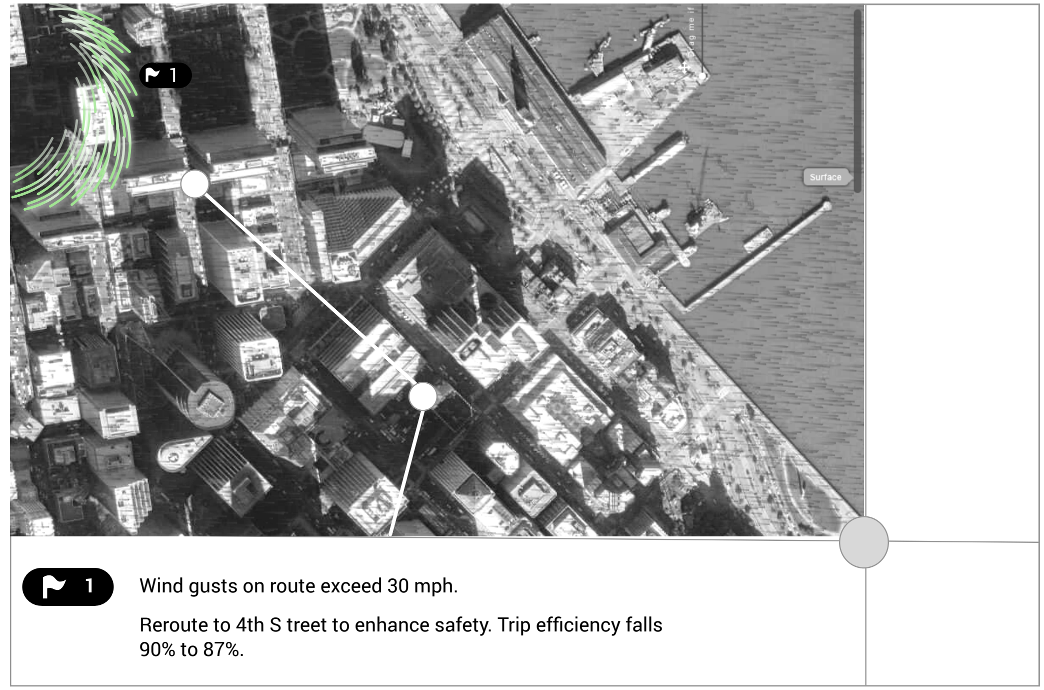


Visual Route Planning: Explanation of automation decisions



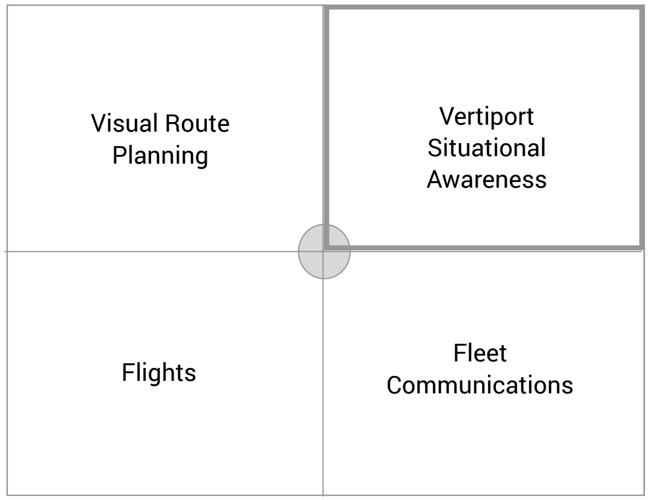


Visual Route Planning: Weather incident spotted by the system on a selected route.



Prediction: Winds

While visually planning a route, surface based “microweather cells” play an important role in safety and efficiency. The system looks at active gusts and potential weather cells with extremely accurate data, speed, and granularity. Offering to re-route traffic is based on detecting these fast-moving cells and having predictive models as a guide for change.



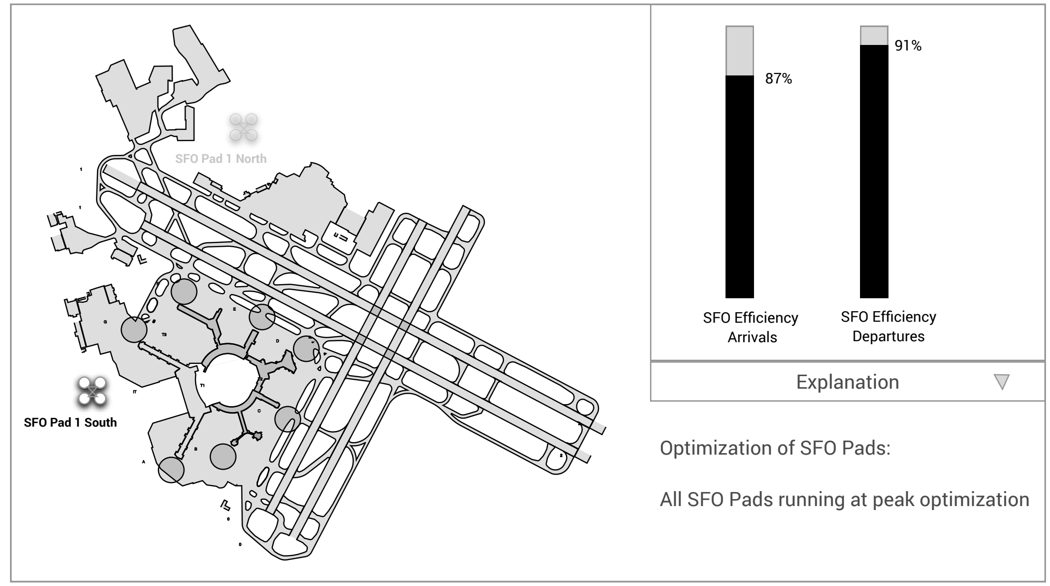
Monitoring

Vertiport Situational Awareness window shows users the level of efficiency at that vertiport.

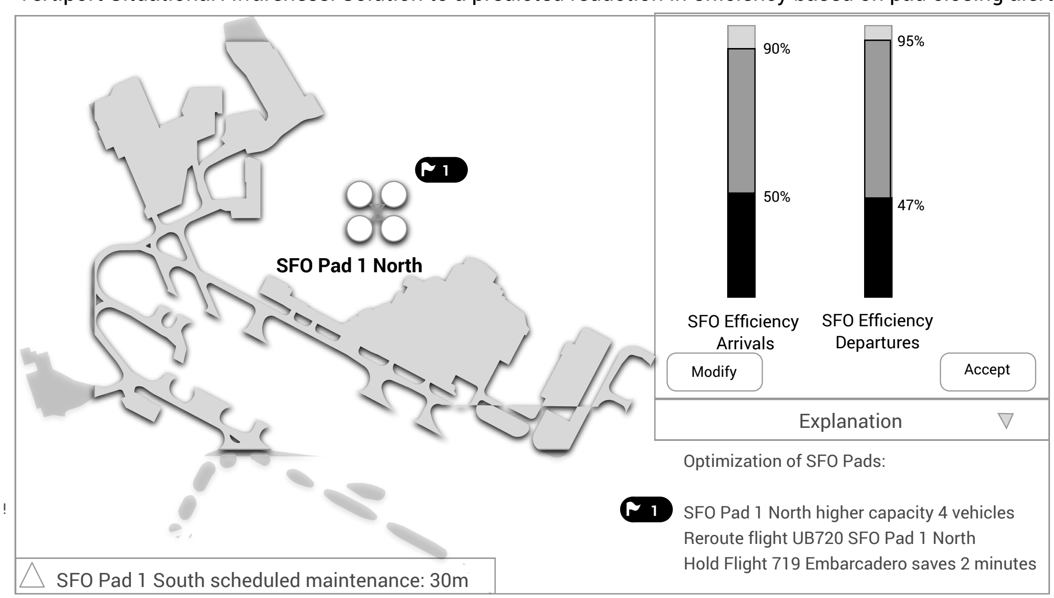
In the top right figure, efficiency is at maximum.

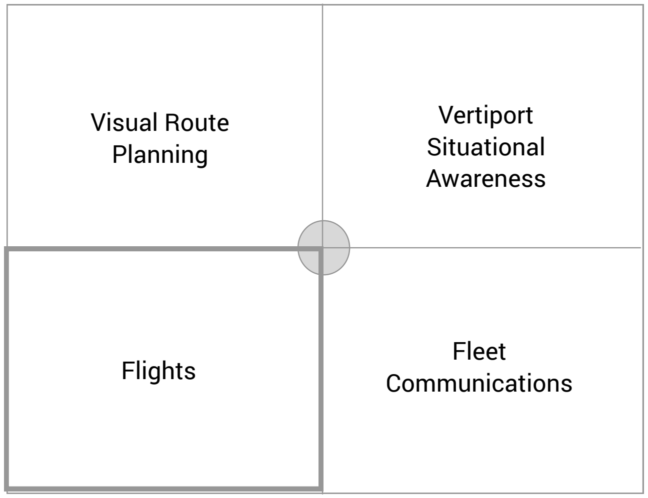
In the bottom right figure, the window shows the current efficiency (in black) against potential efficiency (in dark gray). Suggestions are shown visually on the map or are displayed on demand when user select “Explanation.” Users can then opt to modify or accept the suggestion.

Vertiport Situational Awareness: Local view of the SFO vertiports shows current pad layout and efficiency.



Vertiport Situational Awareness: Solution to a predicted reduction in efficiency based on pad closing alert

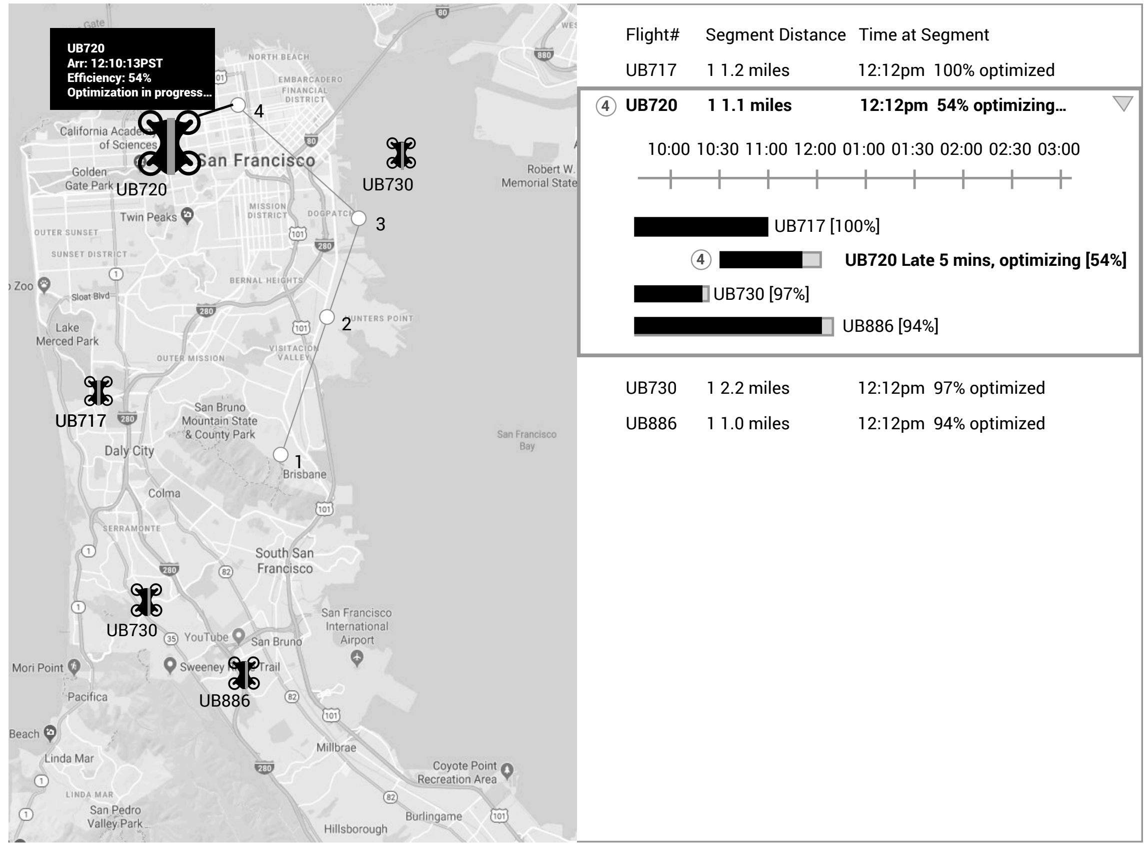


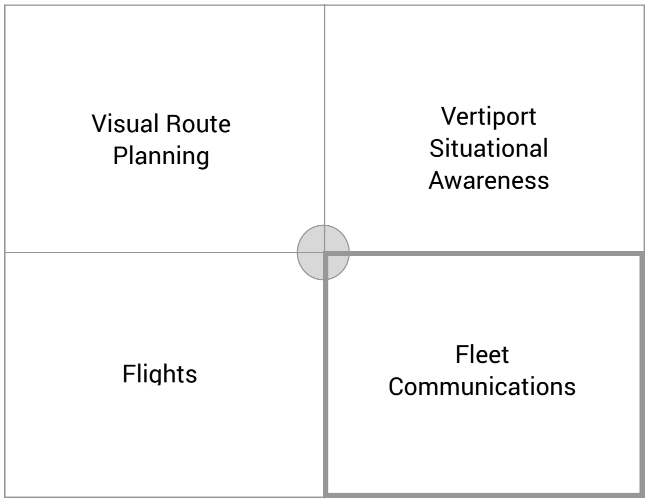


Execution

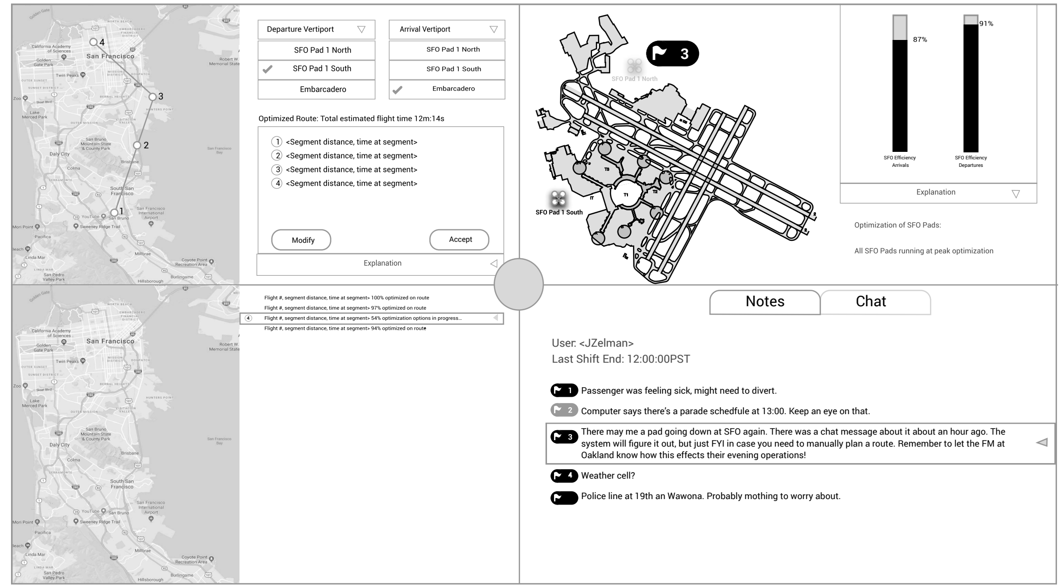
The Flights window shows users all current flights both visually on a map and as a list with corresponding flight number, distance, time, and level of efficiency. Users can select a flight either by clicking on its icon in the map or by selecting the flight list item to get further information about that flight. Here the computer shows that the flight is being optimized and gives users the opportunity to see the result of that optimization prior to being given a choice to accept or modify.

Flight Data: Local view of San Francisco, current planned route. User selects UB720 to understand system optimization.



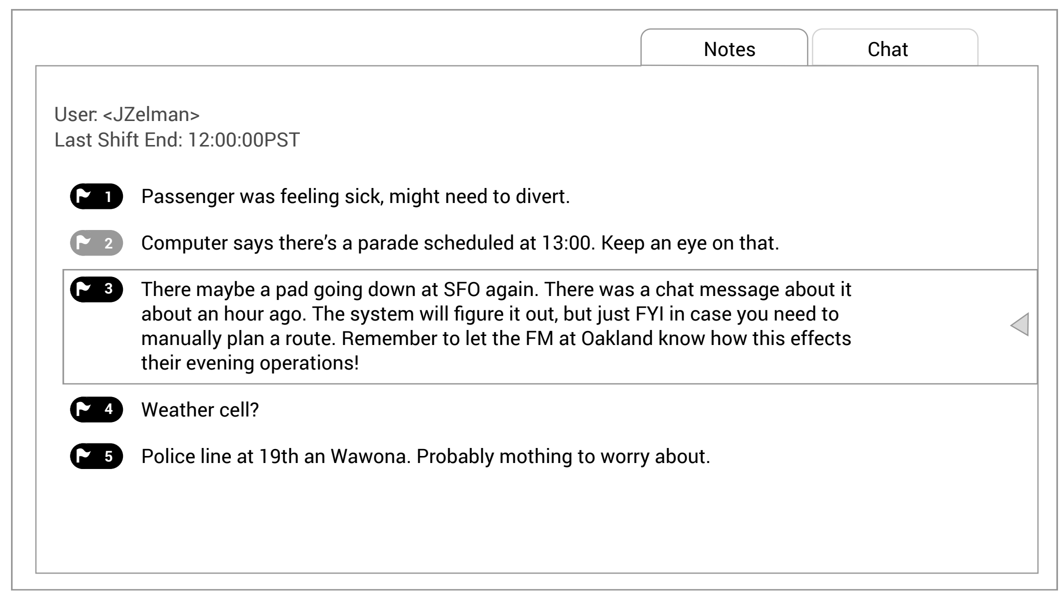


Fleet Communication: Outgoing FM has noted several areas of attention in the interface for incoming FM.



Fleet Communication

Communications with other FMs should be based on shared situational analysis and specific to incidents that are present in the system. For incidents not available to the system, for instance change of shift notes from an outgoing FM to one incoming, the interface should show the particular context for the note, not just textual data. The system allows for maximum autonomy by using contextual inquiry.



Examples of predictive interfaces:

https://arxiv.org/pdf/1811.11960.pdf

https://ieeexplore.ieee.org/document/8814252

https://www.springer.com/gp/book/9783319603681

https://dataplatform.cloud.ibm.com/docs/content/DO/DODS_Introduction/modelbuilderUI.html#ModelBuilderInterfacesolution

References

[1] N. Lavars, "8 flying taxis that are so crazy, they just might work," newatlas.com, para. 15, Feb. 12, 2018. [Online]. Available: https://newatlas.com/eight-flying-taxis/51726/. [Accessed Oct. 12, 2019].